ELECTRONIC TRAJECTORY
MEASUREMENTS GROUP

STANDARD 264-04

MISSILE APPLICATION CONDENSED MESSAGE (MACM) DATA FORMAT

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15. SUBJECT TERMS
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MISSILE APPLICATION CONDENSED MESSAGE (MACM) DATA FORMAT

DECEMBER 2004

Prepared by

Electronic Trajectory Measurements Group
Range Commanders Council

Published by

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Range Commanders Council
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ABSTRACT

This document provides the standard message format for Global Positioning System (GPS) receivers used in high dynamic air/ground missile testing applications. The message, Missile Application Condensed Message (MACM), is a data format designed for high-speed output of raw GPS measurement data. This format provides the minimum data necessary to generate a kinetic carrier-phase measurement of receiver position in a near real-time or post-mission GPS signal processor. The carrier-to-noise ratio, carrier phase measurement, pseudorange, doppler shift, elapsed lock time, and condition flags are supplied for each satellite under track.

This standard affords flexibility to meet the specific needs of ranges. It is intended to be a living document with the ability to respond to changes and to future developments in GPS and range testing requirements.

Commonly used scientific abbreviations/symbols are defined in standard reference dictionaries. Definitions of abbreviations and acronyms with special applications to this document are included where the term first appears or in the chapter entitled Data Descriptions.

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Table Of Contents

List Of Tables

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1. Introduction

The Electronic Trajectory Measurements Group (ETMG) of the Range Commanders Council (RCC) has prepared this document to define a data message format for use in missile testing applications. The intent is to foster compatibility in the exchange and analyses of these type data among the member ranges operating under the cognizance of the RCC. This document defines a standard data message format comprised of GPS receiver output data and related parameters. The message format was developed to optimize data output and data transmission in air/ground missile testing applications that require high-speed data output within test communications bandwidth limitations of the user range.

The data format is a Fixed Packed Record (FPR) consisting of a header field, structure of each satellite under track, and a checksum for the message. The Missile Application Condensed Message (MACM) length depends on the number of satellites being tracked. Table 1, Parameters of the MACM Message, provides the actual variables of the MACM record. Table 2, Example MACM Data Record Format, presents an example of the message makeup, including the number of data bytes for each parameter, for a MACM record with seven satellites under track. Table 3, MACM Data Field Definitions, provides detail descriptions for each variable in the MACM message.

Table 1. Parameters of the MACM Message
a. Name of message b. Version of code c. Number of remaining satellites structures in the message d. GPS time tag e. Receiver clock offset f. Satellite identification number g. Satellite status h. Signal to noise ratio at the receiver i. Carrier phase counter output j. Pseudorange from satellite to receiver k. Rate of change of carrier phase counter l. Time satellite is under continuous track m. Message checksum byte
Note: Further definition and description of these individual parameters is provided in Table 2, Table 3, and in Paragraph 2, Data Descriptions, of this standard.

Table 2. Example MACM Data Record Format		
Data	**Function**	**Total Bytes**
[MACM:4] [VERSION:1] [NUMOBS:1] [GPSTIME:4] [OFFSET: 4]	Header	14
[PRN:1][CONDITION:2][CN0:1][PHASE:8][PSRNGE:4][RATE:4][LCK_TIME:4]	OBSERV'N	24
[PRN:1][CONDITION:2][CN0:1][PHASE:8][PSRNGE:4][RATE:4][LCK_TIME:4]	OBSERV'N	24
[PRN:1][CONDITION:2][CN0:1][PHASE:8][PSRNGE:4][RATE:4][LCK_TIME:4]	OBSERV'N	24
[PRN:1][CONDITION:2][CN0:1][PHASE:8][PSRNGE:4][RATE:4][LCK_TIME:4]	OBSERV'N	24
[PRN:1][CONDITION:2][CN0:1][PHASE:8][PSRNGE:4][RATE:4][LCK_TIME:4]	OBSERV'N	24
[PRN:1][CONDITION:2][CN0:1][PHASE:8][PSRNGE:4][RATE:4][LCK_TIME:4]	OBSERV'N	24
[PRN:1][CONDITION:2][CN0:1][PHASE:8][PSRNGE:4][RATE:4][LCK_TIME:4]	OBSERV'N	24
[CHECKSUM:1]	CHECKSUM	1

Note: The number after the colon is the number of bytes associated with each field.

In the example above, a message with 7 satellites reported, is 183 bytes long.

The definitions of the individual data fields within the MACM message are given in Table 3, MACM Data Field Definitions.

Table 3. MACM Data Field Definitions			
Byte #	Name	Type	Content
1	MACM	long	Sync_word (Name of message, ASCII "MACM")
5	VERSION	unsigned char	MACM version number
6	NUMOBS	short	Number of remaining structures to be sent for the current epoch. (Each structure is one satellite.)
7	GPSTIME	long	Signal received in milliseconds of week GPS system time. This is the time tag for all measurements and position data.
11	OFFSET	float	Receiver clock offset in meters.
24*j-9	PRN	unsigned char	Satellite PRN number
24*j-8	CONDITION	unsigned short	Manufacturer defined warning and condition flags
24*j-6	CN0	unsigned char	Signal-to-noise ratio of satellite observation (dB)
24*j-5	PHASE	double	Full carrier phase measurements in cycles.
24*j+3	PSRNGE	unsigned long	Pseudo-range in seconds, scale factor = 3.0e10
24*j+7	RATE	long	Rate of change of carrier phase, positive for increasing range. Scale factor =1x 10^{-4} Hz. Doppler (10^{-4} Hz)
24*j+11	LOCKTIME	unsigned long	Continuous counts since satellite is locked. This number is to be incremented 500 times per second
24*N+15	CHECKSUM	unsigned char	Checksum includes bytes 5 through the end of the message. (Checksum does not include bytes 1-4 nor the checksum byte its self.)

Notes:

- j = 1,2, ..., N; where N = # of records in the message (# of SVs, value of byte #6).
- The message is variable in length. The number of 24-byte structures is defined by the value of byte #6 in the header.
- The message begins with the 4 byte sync word [4D 41 43 4D] (ASCII "MACM") and ends with the checksum byte.
- The checksum is computed by the bit-by-bit exclusive-*oring* of all bytes in the block of data defined in the table.
- Time synchronization of observations: Times of validity for MACM records are required to be aligned with GPS time to within one hundred microseconds.
- All parsing is done by counting from the sync_word.

2. Data Descriptions

Interpretation of individual data values are provided below.

2.1. Header Fields

Name: MACM

This is the four-byte synchronization word ("sync_word" [4D 41 43 4D]), which identifies the start of a MACM message in the midst of a stream that includes both MACM messages and other information. All data fields in the MACM message are found by counting forward from the location (offset) of the sync word.

Name: VERSION

This is a single byte that is assigned to indicate version number of the MACM format.

Name: NUMOBS (Abbreviation for "Number of Observations")

This is a single byte whose (hexadecimal) numeric value is the number of satellite vehicles that are being tracked by the receiver, and whose data are being reported in the body of this message. For example, a value of "0a" indicates that 10 satellites are being reported.

Name: GPSTIME

This is the four-byte GPS time of validity (called the epoch) of this particular MACM message. The times are reported in milliseconds. A GPSTIME value of 245380000 is a GPS time value of 245,380.000 seconds of the GPS week (Tuesday, 20 hours, 9 minutes, 40 seconds). Note: this differs from GMT (Greenwich Mean Time) by the current number of leap seconds.

Times of validity for MACM records are required to be aligned with GPS time to within 100 microseconds. For example, for a MACM reporting rate of 100 messages per second, one message should be valid at 245,380.0000 ± .0001 GPS seconds, the next at 245,380.0100 ± .0001, then 245,380.0200 ± .0001, etc.

Name: OFFSET

This is the (residual) four-byte GPS receiver clock offset, in meters. Part of the tracking process for GPS receivers is to align the receiver clock with the true GPS time, as broadcast by the individual satellites. The clock offset is the residual error in this alignment, after the best fit has been calculated.

2.2. Satellite Vehicle Fields

There is one record for each satellite being reported.

Name: PRN (Abbreviation for "Pseudorandom Noise")

This is the single byte pseudorandom noise identification number of the satellite.

Note: Each GPS satellite has three identification numbers, a Launch Order number, an SVN (Satellite Vehicle Number) and a PRN number. The Launch Order number is the order of satellites as they were launched. The SVN number is a serial number of the GPS satellite, assigned as it is manufactured. A typical Launch Order number is "BIIA-16", which is Block IIA satellite, and was the sixteenth Block II satellite to be launched. The SVN number of BIIA-16 is 32.

As each satellite is activated, it is assigned a PRN number ranging from 1 to 32. The PRN number is actually a key number that permits the GPS receiver to demodulate the encoded GPS signal from that particular satellite. Satellite BIIA-16 is currently (April, 2000) assigned PRN number 1.

Some satellite tracking programs identify the individual GPS satellites by Launch Order number rather than PRN number. When using these tracking programs (particularly programs that use two-line-ephemeris [".tle"] orbital data), one must determine which ID number is used as an identifier. One place to find this information is on the US Naval Observatory's GPS Web Site (http://tycho.usno.navy.mil/gpscurr.html).

Name: CONDITION

This is a status byte (two bytes) that is set by the receiver. These two bytes are reserved for the sensor manufacturer to place track condition flags, warning flags, etc. The CONDITION field must include a flag that is set if the number reported for PHASE is not valid. The CONDITION field must also contain a flag that is set TRUE (for one message duration) when the PSRNGE field value is updated, and is FALSE otherwise.

Name: CN0 (Abbreviation for "Carrier to Noise Ratio")

This is a single byte carrier-to-noise ratio (in dB-Hz units) of the signal. The carrier power (in watts) received by the GPS receiver is the input signal flux, "Signal", times the antenna gain, "AntGain". ("Signal" is defined as the signal power density that flows through an antenna whose area [aperture] is the equivalent of unity gain.) The (receiver-generated) noise power density is Boltzmann's constant "k" times the receiver noise temperature "Tr". ("Tr" is a standard measure of merit for RF receivers). The noise power density units are watts per unit bandwidth, or watts per hertz. The resulting quotient is:

C/N0 = (Signal*AntGain)/(k*Tr)

and has units of Hertz.

The reported value is this number, converted to dB. Typically values over 30 dB-Hz are considered good carrier-to-noise ratios.

Name: PHASE

This is an eight-byte output of the receiver phase cycle counter. The output is in whole numbers and fractions of a carrier cycle. Each L1 carrier cycle is approximately 19.0 cm. in length, and so each change in the PHASE value of ± 1.0 represents a change in range between the satellite and the receiver of ±19 cm. The PHASE counter in MACM messages decrements as the range decreases, and increments as the range increases.

GPS receivers, equipped with the proper options, report the results of carrier tracking on each satellite. If satellites and earth locations were stationary, a receiver with an oscillator tuned to exactly the GPS transmission frequency (1575.42 MHz exactly for L1, for example) could compare the phase to the broadcast satellite carrier phase, and the difference would be a steady voltage. Satellites are moving, however, and the range between them and the receiver varies. As the range closes, for instance, the total number of carrier wavelengths between the satellite and receiver decreases. The receiver's difference detector will see this difference, outputting a complete sine-wave cycle for each whole-cycle decrease in range. Carrier tracking receivers contain counters that count these difference cycles.

Phase counters both count whole numbers of cycles, and measure fractions of a cycle, in their output data. Some receiver counters use a double precision floating point number definition for the phase number, which has approximately the number of significant figures shown in the interpretation sections of Table 4. However, a fraction of a phase less than 0.001 cycle is not significant data. When the satellite is first put under track, the counters may start at an arbitrary initial count. The data that is important is the change in cycle counts from epoch to epoch.

Name: PSRNGE (Abbreviation for "Pseudorange")

This is the measured (with corrections) pseudorange from the satellite to the receiver, in seconds. The measurement is scaled by a multiplication factor of 3.0x10^10. To convert to pseudorange in meters,

Pseudorange = [(speed of light)/3.0x10^10] x (RANGE) = [0.999308193x10^(-2)] x (RANGE).

The "GPS propagation constant" is 2.99792458x10^8 m/sec.

The pseudorange value is required to be updated at the MACM message rate. The update time of validity must be synchronized to GPS time, to within the same accuracy as the time of validity of the overall MACM message (100 microseconds). For example, the first update time for a pseudorange update might be 245,380.0000 ± .0001 GPS seconds, the next would occur at 245,380.1000 ± .0001 seconds, the next at 245,380.2000 ± .0001, etc.

For MACM messages where the pseudorange is not updated, the value of the last updated pseudorange is repeated. (Note that the CONDITION field will contain a flag that is TRUE at the message where pseudorange is valid, and is FALSE for messages where the pseudorange is not updated.)

Name: RATE

This is the measured rate of change of the cycle counter (PHASE), in units of 10^(-4) cycles per second. To convert to cycles per second, multiply the reported number by 0.0001.

There is (or should be) a close correlation between the DOP (Dilution of Precision) rate and the total increment/decrement in the PHASE number from epoch to epoch. The sign convention for the MACM message is that DOP is positive for increasing range and PHASE count. BEWARE: This sign convention is the opposite of the actual Doppler shift of the GPS carrier. It is also the opposite to the Doppler definition of the Rinex 2 (Receiver Independent Exchange) file convention.

Name: LOCKTIME

This is a four-byte time counter that is incremented at a constant 500 count per second rate for as long as an individual satellite is maintained in continuous track. If the lock time counter is reset, track has been (temporarily) broken. This means, in particular, that the PHASE counter may have missed some changes in cycles while track was broken. (This phenomenon is called "cycle slips".)

2.3. Checksum Byte

Name: CHECKSUM

The checksum byte is a method of detecting errors in the message file. The checksum is computed by the bit-by-bit exclusive-*oring* of all bytes in the block of data defined in the table and is appended to the end of the message. As an example, the checksum of

(1001 0110),
(1000 0101),
and (1100 0001)

is (1101 0010)

Users of the data should also, independently, calculate what the checksum should be, and compare it to the transmitted value. A mismatch indicates that this particular message is corrupted.

Notes:

1) The checksum does not provide any way to correct the message. The only choice for the user is to delete the message.

2) The checksum is not infallible, in other words it is possible for corrupted files to generate a correct checksum.

3. MACM Example

The MACM message can readily be interpreted when viewed on a hexadecimal viewer/editor. Table 4 shows a pair of actual MACM messages.

Table 4. Example of MACM Hexadecimal Messages

Byte	Byte Number																								ANSI Character
Offset	0	1	2	3	4	5	6	7	8	9	a	b	c	d	e	f	10	11	12	13	14	15	16	17	
000000		00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	....
000018		00	4d	41	43	4d	02	06	0e	a0	0c	90	40	7c	10	00	02	02	05	24	c1	1c	27	ad	.MACM... ..@|.....$Á.'-¶
000030		83	39	e0	7a	b4	24	64	00	96	be	29	00	09	6d	48	18	0a	05	29	c1	39	82	89	.9àz´$d..¾)..mH...)Á9..|
000048		1b	61	a4	89	33	d2	34	fe	43	11	7e	00	00	95	6a	07	02	05	2b	c1	33	4f	3c	.a¤.3Ò4þC.~...j...+Á3O<.
000060		05	a3	14	7e	58	d9	a6	00	0d	96	3b	00	0a	49	cb	09	aa	00	28	c1	3d	92	f9	.£.~XÙ¦...;..IË.ª.(Á=’ùT
000078		e0	d4	a0	8c	d4	36	fa	ff	63	5c	85	00	00	04	65	0e	02	05	25	c1	2d	bf	f5	àÔ .Ô6úÿc\....e...%Á-¿õ¹
000090		4d	05	18	8b	f8	67	a3	00	80	9c	42	00	09	cb	08	10	00	05	26	c1	37	44	bb	M...øg£...B..Ë....&Á7D»}
0000a8		0b	c6	e0	84	a7	1c	e7	ff	41	00	68	00	00	60	c7	27	00	00	00	00	00	00	00	.Æà.§.çÿA.h..`Ç'........
0000c0		00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	....
0000d8		00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	....
0000f0		00	00	00	00	00	00	00	00	00	00	00	00	00	4d	41	43	4d	02	06	0e	a0	33	a0	.............MACM... 3 ?
000108		b8	c0	00	02	02	05	22	c1	1b	8d	09	d0	27	ee	00	7a	b7	03	4b	00	97	7d	25	¸À...."Á...Ð'î.z·.K..}%.
000120		09	80	d0	18	0a	05	28	c1	39	f4	6a	4c	f5	33	d0	89	2b	59	77	fe	43	7e	7a	..Ð...(Á9ôjLõ3Ð.+YwþC~z.
000138		00	a8	f2	07	02	05	2e	c1	33	4b	c5	3d	b7	31	a0	7e	59	1b	77	00	0d	bf	cf	.¨ò....Á3KÅ=·1 ~Y.w..¿Ï.
000150		0a	5d	53	09	aa	05	29	c1	33	ab	98	8d	f9	f9	80	8c	d1	3b	75	ff	64	11	ad	.]S.ª.)Á3«..ùù..Ñ;uÿd.-.
000168		00	12	d9	0e	02	05	25	c1	2d	7d	f9	a9	25	17	a0	8b	fa	db	bc	00	81	70	cf	..Ù...%Á-}ù©%. .úÛ¼..pÏ.
000180		09	de	90	10	00	05	26	c1	37	75	8e	e2	62	4e	40	84	a3	7a	fc	ff	41	d6	cc	.Þ....&Á7u.âbN@.£züÿAÖÌ.
000198		00	74	4f	3a	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	.tO:....................
0001b0		00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	

This sample contains two MACM messages. The first begins at offset byte 000019h, and ends at byte 0000b7h. The next message starts at byte 0000fdh, and ends at 00019bh. Note that the messages may be preceded and followed by other bytes that are not part of the MACM message itself. These bytes are shown as zeroes, but may actually be any valid binary data stream, of any length. (The extra bytes, however, should not be so numerous that the message rate cannot be met.) Table 5 is the interpretation of the first of the two MACM messages from the example above.

Table 5. Interpretation of a Sample MACM Message

MACM	VERSION	NUMOBS	GPSTIME	OFFSET			Field Name
4d 41 43 4d	02	06	0e a0 0c 90	40 7c 10 00			Hex
ASCII Text	2	6	245370000	3.938477			Interpretation
PRN	**CONDITION**	**CN0**	**PHASE**	**PSRNGE**	**RATE**	**LCK_TIME**	**Field Name**
02	02 05	24	c1 1c 27 ad b6 83 39 e0	7a b4 24 64	00 96 be 29	00 09 6d 48	Hex
2	Manufacturer	36 (dB)	-461291.428234962747	2058626148	9879081	617800	Interpretation
PRN	**CONDITION**	**CN0**	**PHASE**	**PSRNGE**	**RATE**	**LCK_TIME**	**Field Name**
18	0a 05	29	c1 39 82 89 7c 1b 61 a4	89 33 d2 34	fe 43 11 7e	00 00 95 6a	Hex
24	Manufacturer	41	-1671817.48479280714	2301874740	-29159042	38250	Interpretation
PRN	**CONDITION**	**CN0**	**PHASE**	**PSRNGE**	**RATE**	**LCK_TIME**	**Field Name**
07	02 05	2b	c1 33 4f 3c 9e 05 a3 14	7e 58 d9 a6	00 0d 96 3b	00 0a 49 cb	Hex
7	Manufacturer	43	-1265468.61727351416	2119752102	890427	674251	Interpretation
PRN	**CONDITION**	**CN0**	**PHASE**	**PSRNGE**	**RATE**	**LCK_TIME**	**Field Name**
09	aa 00	28	c1 3d 92 f9 54 e0 d4 a0	8c d4 36 fa	ff 63 5c 85	00 00 04 65	Hex
9	Manufacturer	40	-1938169.33155564219	2362717946	-10265467	1125	Interpretation

Table 5. Interpretation of a Sample MACM Message (continued)

PRN	CONDITION	CN0	PHASE	PSRNGE	RATE	LCK_TIME	Field Name
0e	02 05	2b	c1 2d bf f5 b9 4d 05 18	8b f8 67 a3	00 80 9c 42	00 09 cb 08	Hex
14	Manufacturer	43	-974842.86191574018	2348312483	8428610	641800	Interpretation
PRN	**CONDITION**	**CN0**	**PHASE**	**PSRNGE**	**RATE**	**LCK_TIME**	**Field Name**
10	00 05	26	c1 37 44 bb 7d 0b c6 e0	84 a7 1c e7	ff 41 00 68	00 00 60 c7	Hex
16	Manufacturer	38	-1524923.48846095055	2225544423	-12517272	24775	Interpretation
CHECK SUM							**Field Name**
27							Hex
							Interpretation

4. **Testing And Verification**

The MACM message format has been implemented, tested, and verified in two separate manufactures GPS receivers, the Parthus NS-100M GPS Receiver circuit card assembly and Thales Navigation (Ashtech) G12 GPS Receiver. Results of the Parthus NS-100M GPS TSPI Receiver Circuit Board tests were documented in the following reports by the 46th Test Wing, Eglin AFB FL:

Acceptance Test Results	Serial Number 128501	14 February 2003
Acceptance Test Results	Serial Number 129747	14 February 2003
Acceptance Test Results	Serial Number 135577	14 February 2003
Acceptance Test Results	Serial Number 139699	14 February 2003
Acceptance Test Results	Serial Number 141131	14 February 2003

These tests followed Joint Advanced Missile Instrumentation (JAMI) Test Plan TP 543-006 in accordance with the Master Test Plan for the GPS TSPI Receiver Assembly, Document CDM 00-543/032.

5. **Format Maintenance/Updating**

This document shall be maintained and updated by the Electronics Trajectory Measurements Group of the Range Commanders Council and is intended to meet the needs of the ranges for high-speed output of raw GPS measurement data and post-test data exchange of GPS data.